



Research and Development

GREENHOUSE GASES FROM
SMALL-SCALE COMBUSTION DEVICES
IN DEVELOPING COUNTRIES: PHASE IIA
Household Stoves in India

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FOREWORD

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GREENHOUSE GASES FROM SMALL-SCALE COMBUSTION DEVICES IN
DEVELOPING COUNTRIES

Phase IIa

Household Stoves in India

by

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FOREWORD

Early in the 1990s, a pilot study was conducted in Manila, Philippines, to measure the concentrations of a range of greenhouse gases from small-scale cookstoves burning biomass, charcoal, kerosene and liquefied petroleum gas (Smith *et al.*, 1992; 1993). Based on intriguing results, a more comprehensive study to characterize the emissions of non-CO₂ gases and other pollutants from cookstoves using different solid, liquid, and gaseous fuels was undertaken in China and India under a project organized by East-West Center (EWC) and funded by the US Environmental Protection Agency (USEPA). The study focuses on more than two dozen of the most common fuel/stove combinations in each nation. Since these countries contain more than half of all stoves in developing countries, the stoves in this study represent a large fraction of the combinations in use world-wide. In this report we describe the methodology and results of the study undertaken in India. The monitoring took place in a simulated kitchen built at the Gual Pahari Campus of the Tata Energy Research Institute (TERI), just outside New Delhi. Laboratory analyses took place at TERI and at the Oregon Graduate Institute of Science and Technology (OGIST).

ABSTRACT

This report presents a database containing a systematic set of measurements of the CO₂, CO, CH₄, TNMOC, N₂O, SO₂, NO₂, and TSP emissions from the most common combustion devices in the world, household stoves in developing countries. A number of different stoves using 8 biomass fuels, kerosene, LPG, and biogas were examined – a total of 28 fuel/stove combinations. Since fuel and stove parameters were monitored as well, the database also allows examination of the trade-off of emissions per unit fuel mass, fuel energy, and delivered energy as well as construction of complete carbon balances. Confirming the preliminary results in the Manila pilot study, the database shows that solid biomass fuels are typically burned with substantial production of PIC (products of incomplete combustion). In addition, as has often been shown in the past, biomass stoves usually have substantially lower thermal efficiencies than those using liquid and gaseous fuel. As a result, the emissions of CO₂ and PIC per unit delivered energy are considerably greater in the biomass stoves. In general, the ranking follows what has been called the “energy ladder” from lower to higher quality fuels, i.e., emissions decrease and efficiencies increase in the following order: dung-crop residues-wood-kerosene-gas. There are variations, however, depending on specific stove designs.

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GLOSSARY

Acacia	tree used as source of woodfuel in tests
BIS	Bureau of Indian Standards
COV	coefficient of variation = (standard deviation)/(mean)
EF _{bc}	emission factor per burn cycle experiment
EF _d	emission factor per MJ delivered to cooking pot (MJ _d)
EF _e	emission factor per unit net energy (MJ) of fuel
EF _m	emission factor per unit mass (kg) of fuel
Emission ratio	EF _{bc} molecular ratio of emitted specie (e.g., CO) to emitted CO ₂
EPA	U.S. Environmental Protection Agency
ESI	Environmental Stove Index
Eucal	Eucalyptus, tree used as source of woodfuel in tests
EWC	East-West Center, Honolulu, HI
GHG	greenhouse gas (in this report: CO ₂ , CH ₄ , N ₂ O, CO, TNMOC)
Gross carbon balance	distribution of fuel carbon into gases, ash, char, and aerosol
GWC	global warming commitment = sum over i of GHG _i *GWP _i
GWP ₁	global warming potentials in kg C as CO ₂ per kg C in GHG (20-year time horizon) CO ₂ = 1.0, by definition CO = 4.5 (IPCC, 1990) CH ₄ = 22.6 (IPCC, 1995) TNMOC = 12 (IPCC, 1990) N ₂ O = 290 (IPCC, 1995), on a molar basis with CO ₂ In the renewable case, 1.0 is subtracted from each (except N ₂ O) to account for the recycling of C as CO ₂ in photosynthesis. Basic set - those with specified GWP in IPCC (1995) Full set - those with specified GWP in IPCC (1990, 1995)
Hara	traditional unvented mud stove for use with dung
HTE	heat transfer efficiency = η /NCE
imet	improved metal stove (unvented)
Instant emissions	from combustion of original fuel, with char left unburned
IPCC	Intergovernmental Panel on Climate Change
IREP	Integrated Rural Energy Planning Programme
ivc	improved vented ceramic stove
ivm	improved vented mud stove
Kero-pres	pumped kerosene stove (unvented)
Kero-wick	simple wick kerosene stove (unvented)
KVIC	Khadi and Village Industries Commission
LPG	liquefied petroleum gas contained in pressurized cylinders: butane and propane
MJ _d	megajoule delivered to the cooking pot
MNES	Ministry of Non-Conventional Energy Sources
NCAEC	National Council for Applied Economic Research

NCE	nominal combustion efficiency = fraction of airborne carbon emissions released as $\text{CO}_2 = 1/(1+K)$ see Eq. 2
OGIST PIC	Oregon Graduate Institute of Science and Technology, Beaverton airborne products of incomplete combustion (CO , CH_4 , TNMOC, TSP)
REDB	Rural Energy Database
ren	renewable, as in GWC (ren)
SRK	simulated rural kitchen
TERI	Tata Energy Research Institute, New Delhi
3-R	traditional 3-rock stove (unvented)
Tg	teragram = 10^{12} g = one million tons
tm	traditional mud stove (unvented)
TNMOC	total non-methane organic compounds (molecular weight taken as 18/carbon atom)
Tons	metric tons
TSP	Total Suspended Particulates
Ultimate emissions	instant emissions plus emissions from burning leftover char
η	overall energy efficiency of a stove (Appendix D)

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